Home
About Patents
Patent Search
Content
Terms & Conditions
Glossary
Other Collections
PCT Resources
PCT Electronic Filing
Patent & Technical Information
Statistics
Law of Patents
Meetings
E-mail Updates
Contact

Related Links
International Patent Classification
Natural Language IPC Search
Standards & Documentation

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(WO/2004/008259) MECHANICAL OSCILLATOR SYSTEM

Biblio. Data | Description | Claims | National Phase | Notices | Documen

MECHANICAL OSCILLATOR SYSTEM The present invention relates to a mechanical oscill balance and balance spring for use in horological mechanisms (e. g. timekeeping devices) c instruments. It is thought that it will be particularly applicable to the oscillator system in a me the present invention is not limited to this.

Previous mechanisms use metal alloys, in particular Fe-Ni or Ni, Cu-Be, Au-Cu alloys, for th balance. At its most general, in one of its aspects, the present invention proposes that the b magnetic ceramic material and the balance spring is non-magnetic and is made of a compo (including thermoset and thermoplastic polymers, esters and phenolic based resins), carbon ceramic material.

In contrast to metals, the above materials are non- susceptible to the effects of magnetism-i damping and magnetically induced change of the Young's modulus. These materials have s characteristics which are better than metals and so a mechanical oscillator system having re oscillator frequency with temperature can be made. Variation with temperature is discussed balance spring of the above materials may be less susceptible to internal mechanical (e. g. Young's Modulus, allowing amplitude to be maintained by the balance and a higher frequen therefore a more accurate horological mechanism or precision instrument than a metal sprin

The balance spring is arranged to oscillate the balance.

Preferably the balance is a balance wheel; the balance spring may be arranged inside the ci balance wheel so as to oscillate the balance wheel back and forth about its axis of rotation a

The balance may be coupled to an escapement mechanism for regulating rotation of an esc coupled to the hands of a watch), as is also conventionally known.

Preferably the balance spring works in flexion to oscillate the balance, most preferably exclu the balance spring is preferably not relying on strain or shear properties for the repeated sto during its (relatively rapid) oscillations. Preferably the balance spring coils are not in contact a gap between adjacent coils. This eliminates or reduces friction and allows the successive one another.

While the main body of the balance is made of a ceramic material, it may have small appen

Considerations relating to the oscillator frequency and in particular its variation with tempera discussed.

The accuracy of a mechanical watch is dependent upon the specific frequency of the oscilla balance wheel and balance spring. When the temperature varies, the thermal expansion of balance spring, as well as the variation of the Young's Modulus of the balance spring, chang the oscillating system, disturbing the accuracy of the watch. The inventor has noticed that in approximately three quarters of the variation is due to thermal or magnetically induced chan

Methods for compensating these variations are based on the consideration that the specific exclusively upon the relationship between the torque of the balance spring acting upon the t inertia of the latter as is indicated in the following relationship T: the period of oscillation, : th balance wheel, G: the torque of the balance spring.

The moment of inertia of the balance wheel is a function of its masse its radius of gyration r.

The torque of the balance spring is a function of its dimensions: length height h, thickness e Modulus E. The length of the balance spring (which may be helical or spiral form) is the who to end, as distinct from e. g. a top to bottom measurement that varies according to the spaci

The relationship is therefore written: Temperature variations influence T (the period of oscill effects of expansion and contraction of the system (balance spring and balance wheel) h an and r for the balance wheel whose mass m remains constant.

It is known how to compensate for the effects of expansion on h and e. However the period to variations of r and E in keeping with the relationship expressed by: These two terms are r

It is necessary that this relationship should remain as constant as possible (so as to keep th constant).

Fe-Ni metal spring alloys render an approximate solution when the alloy is perfectly de-mag the alloy is not perfectly demagnetised, the relationship is no longer constant: changes.

The currently employed metal alloys for balance springs show an increase in E (which is co also in for an increase in temperature, over the ambient temperature range up to The balan employed in precision watches are of an Au-Cu alloy with a coefficient of thermal expansion compensate for changes in the Young's modulus of the balance spring.

In summary, the currently used metal alloys despite compensation, only allow for the stabilit over a narrow temperature range and only when the balance spring alloy remains un-magne employing a Fe-Ni balance spring may be stopped by a sufficient magnet).

Preferably the balance spring material comprises continuous fibres extending along the leng from one end of said spring to the other end of said spring.

As the fibres are continuous extending along the length of the balance spring from one end which the spring expands (or contracts) with an increase in temperature can be controlled fa appropriate choice of the fibre material.

Preferably the continuous fibres are part of a composite material, although it is possible to h continuous fibres in a non-composite material (i. e. without a matrix, e. g. long ceramic fibre

Where the material is a composite material, preferably the matrix phase comprises a polym discussed above), carbon or a ceramic. In the case of a composite material with ceramic fib continuous fibres extending along the length of the spring from one end of the spring to the or smaller fibres that do not extend all the way along the spring.

Where ceramic fibres are used (with or without a matrix), it is important that the ceramic is a Preferably, but not necessarily, the balance spring ceramic is Alumina-Silica-Boria. Fused q used for the balance.

Preferably the thermal coefficient of expansion of the balance and the thermal coefficient of the balance spring, in the direction along the length of the balance spring, are of opposite si magnitude (i. e. the difference in magnitude between the two is not more than a factor of 6 a coefficients should not be greater than In this way expansion of one can be compensated fo other. For example, if said thermal coefficient of expansion of the balance spring is negative coefficient of expansion of the balance is positive then with an increase of temperature r inc and in accordance with equation [2] these effects combine to assist in compensating for the period of oscillation T.

Preferably said coefficient of expansion are both very small. For example preferably the coe

Preferably said coefficient of expansion are both very small. For example preferably the coe
expansion of the balance is positive and less then and the coefficient of thermal expansion c
balance spring in the direction along the length of the balance spring is negative, but greatei

The variation of E (Youngs Modulus) with temperature is also important and is determined b
coefficient which is a measure of the unit change in Young's Modulus per unit increase in tei

Preferably the thermoelastic coefficient of the material of the balance spring is negative ; mc
temperature range 0 to 60 degrees Celsius.

In general, the formula for timekeeping changes (U) consequent upon a rise in temperature
to tend to zero when suitable values of a1 (balance coefficient of thermal expansion), a2 (ba
thermal expansion) and the thermo-elastic coefficient are selected by selection of appropriat

The tolerances represented by small (e. g. less than 6 and a small thermo-elastic value allo\
to be kept low.

Preferably the continuous fibres are ceramic fibres or carbon fibres, most preferably carbon
carbon structure. Graphitic carbon structure has a negative longitudinal coefficient of therma
may for example be produced from a "PITCH"precursor or a polyacrilonitrile"PAN"precursor

The fibres may be laid parallel to each other along their lengths, or may be twisted together.
together modulates the coefficient of thermal expansion and Young's Modulus of the balanc
be useful where the fibres have a high and the matrix a low Young's Modulus or coefficient c

Preferably the coefficient of thermal expansion of the balance spring material in the directior
balance spring is linear up to 700° Kelvin. This allows the system to be very stable in the am
compensate for thermal variations over a large range. Preferably said coefficient of thermal

Preferably the damping of the modulus of elasticity of the balance spring is of the order of 0.

Preferably the density of the composite material of the balance spring is less than

Preferably the balance is formed by high precision injection moulding.

Further aspects of the present invention also provide a horological mechanism or other prec
comprising the above described mechanical oscillator system.

An embodiment of the invention will now be described.

A mechanical oscillating system for use in a horological mechanism or other precision instru
balance, in the form of a balance wheel, and a balance spring arranged to oscillate said bala
rotation.

The balance wheel is made of a non-magnetic ceramic for which the coefficient of thermal e
less than +6 most preferably less than 1 Quartz is one example of a suitable material.

Preferably high purity fused quartz is used, fused quartz has a coefficient of thermal expans
ceramic materials include Aluminium Nitride (+5.2), Alumino-Silicate-Glass Boron Carbide (-
Silica (+0.75), Silicon hot-pressed or reaction bonded (+3.5) and Zirconia (stabilised) ; the nı
indicate the order of magnitude of the coefficient of thermal expansion of these materials in ı
fabrication of the balance wheel may preferably be by high precision injection moulding.

The balance spring is shaped into an Archimedes flat spiral or helicoid form. It is made from
comprising continuous carbon fibres which are either twisted or laid parallel to each other, th
lengths of fibres which extend from one end of the spring to the other along the length of the
derived according to the stiffness required from the precursor pitch (a mixture of thousands ı
hydrocarbon and heterocyclic molecules) or polyacrilonitrile PAN' (derived from a carbon gra
fibres are coated and set in a matrix phase of polymer (thermosetting polymer, thermoplasti
phenolic base resin etc), ceramic or carbon. The composite material acts in a flexural mann
elasticity of the fibres is between 230 and The composite has both a lower density less than
of its Young's modulus of the order of (0. 001 pa), both less than the currently employed me

Its thermal expansion coefficient (a) in the direction along the length of the spring remains b Kelvin, and is greater

This composite material is non-magnetic and obviates the negative effects of magnetism. Th expansion a of the spring is negative and acts in parallel with the spring's Young's modulus with a rise in temperature and is therefore negative (normal).

The values of the coefficients of thermal expansion (the a coefficients) for the spring and the small and of opposite sign which further assist in the compensation for temperature variation

The a coefficient of the spring remains the same over a wide temperature range, and the ra represents only at the centre of the total stable temperature range.

Thus, following the relationship: the numerator does not increase in value as is the case with temperature increases because the a coefficient of the fibre composite in the axial sense is diminishes.

The denominator also diminishes when the temperature rises because the thermoelastic co (normal). Furthermore the height (h) and thickness (e) of the carbon fibre-matrix composite increase with temperature which also counteracts the decrease in Young's Modulus E with r

By this combination of materials and their mechanical properties it is possible to obtain both stability. The damping effect of the modulus of elasticity is one tenth of the value of the curre and the reduced energy losses due to the decreased damping and density of the material al maintaining stable amplitude and a significant increase in frequency and significantly reduce the oscillator system.

As has been explained above the present invention can be applied to a conventional mecha time keeping device such as a watch. An example of a conventional mechanical oscillator sy device is illustrated and described on pages 194 to 195 of"How Things Work", volume 1 pub UK, which is incorporated herein by reference.